

transducer may also be placed on the cavity but spaced from an edge thereof. The distance from the transducer to the cavity edge can be chosen to selectively cancel modes.

[0043] The acoustic wave cavity of the present invention has a high Q such as on the order of 400. The amount of energy absorbed by touching the surface 28 of the acoustic cavity in the 1-5 MHz range is not particularly frequency sensitive. A light touch on the surface 28 reduces the Q by a factor of 2.5, i.e. from 400 to 160. As such, by incorporating the transducer into a very basic and simple circuit, a touch on the acoustic cavity touch surface 28 can be easily detected so as to generate a signal indicating actuation of the switch. As can be seen in FIG. 16, a touch on the surface 28 of the acoustic cavity absorbs acoustic energy therein resulting in an easily detectable drop in impedance. For an untouched panel, the impedance of the transducer is at a peak, R_p . In the presence of a touch, the impedance of the transducer drops to a level R_m , below a threshold R_t that can be set as discussed below. By incorporating the transducer 26 into an oscillator circuit as described below with reference to FIG. 9, the drop in impedance indicating a touch can be readily detected. In the absence of touch, the circuit oscillates and in the presence of a touch, oscillation stops. By detecting the state of oscillation, a signal is generated indicating the occurrence of a touch actuating the switch 12.

[0044] FIG. 9 is a diagram of an extremely simple touch detection circuit for a panel 10 having a number of acoustic wave switches 12. Each transducer 26 associated with a respective acoustic switch 12 is coupled to a multiplexer 40 which sequentially couples a transducer and therefore its associated acoustic switch 12 to an oscillator 42. The oscillator 42 includes an operational amplifier 44 having a gain-bandwidth product of 60 MHz. The operational amplifier 44 has two feedback paths. The feedback path 46 connected from the output of the operational amplifier 44 to the negative input terminal thereof sets the static voltage gain to approximately 1.5 through a 47 k Ω resistor 48, a 4.7 k Ω resistor 49 and an 82 k Ω resistor 50. The voltage gain at resonant frequency is approximately 11 because the resistor 50 is bypassed by the 200 pF capacitor 52. The second feedback path of the operational amplifier 44 connects the output thereof to the positive input terminal of the operational amplifier 44 via a 39 k Ω resistor 54 and a 200 pF capacitor 56. The amplifier 44 is connected to a second operational amplifier 58 that detects the state of the oscillator 42 through a 5.6 k Ω resistor 60 and a pair of diodes 62 and 64.

[0045] It can be assumed that the transducer impedance is purely resistive at anti-resonance. With this assumption, the value of the resistor 54 is chosen such that a voltage that exceeds $1/A_v$ of the output, where A_v is the gain of the oscillator at resonant frequency (in this case $A_v=11$), is fed back to the positive terminal of the operational amplifier 44. Under this condition, the operational amplifier 44 will oscillate. If the resistance of the transducer 26 coupled to the operational amplifier 44 is designated R_p and resistor 54 is designated as R_f then the condition for oscillation is as follows.

$$\frac{R_f}{R_p} \leq (A_v - 1)$$

[0046] More particularly, the value of the resistor 54, R_p , is selected such that the acoustic cavity 20 will cause the oscillator 42 to oscillate in the absence of a touch. A touch on the surface 28 of the acoustic cavity 20 will cause the transducer impedance to drop so that the oscillator 42 stops oscillating. The operational amplifier 58 is biased so that the input level matches the quiescent output of the oscillator circuit 44 with diodes D1 and D2 acting as threshold switches. When the operational amplifier 44 is oscillating, the operation amplifier 58 has a high output whereas in the quiescent condition the output of the operational amplifier 58 is low or zero. Thus, the operational amplifier 58 generates a low or zero signal in the presence of a touch and in the absence of a touch the output is high. It should be appreciated that touch detection circuits other than as depicted in FIG. 9 may be used in accordance with the present invention as well.

[0047] In a preferred embodiment, the transducer 26 is mounted on a surface of the acoustic touch panel such that the surfaces 71 and 72 of the transducer 26, across which a voltage is applied to excite the transducer, are parallel to the plane of the substrate 14 and/or the plane of the touch surface 28 of the acoustic cavity 20. It has been found that mounting the shear transducer in this manner generates a shear wave having a harmonic mode with $n \geq 1$ without generating the fundamental or zeroth order mode of the shear wave. This is opposed to the manner in which shear wave transducers are typically mounted on a substrate to generate a shear wave in the plane of the substrate. The typical arrangement mounts the transducer such that the surfaces across which the voltage is applied to excite the transducer are perpendicular to the plane of the substrate and touch surface, for example on a side of the substrate as opposed to the top or the bottom of the substrate as in the present invention. It has been found, however, that shear waves of higher order modes, i.e. $n \geq 1$, will be generated in the plane of the substrate, as depicted in FIG. 4, without generating a substantial fundamental mode shear wave by mounting the transducer such that the surfaces 71 and 72 thereof are parallel to the plane of the substrate and/or touch surface. It should be appreciated, however, that other mounting positions of the transducer 26 will generate the desired higher order modes of the shear wave without generating a substantial fundamental shear wave mode. For example, the transducer 26 may be mounted on a side 74 of the mesa where the side is appropriately angled so that it is not perpendicular to the plane of the substrate. This mounting method will work but results in a more complicated manufacturing process for the acoustic wave switch 10.

[0048] Further, although it is preferred that the transducer be mounted along a center line of a surface of the acoustic wave cavity as discussed above, the acoustic wave switch 12 will work for other transducer mounting positions, for example, on surface 30 but adjacent an edge 76 thereof. The preferred shear wave transducer materials are Lead Zirconium, Titanate (PZT) types and specifically PZT4D, PZT5A and PZT8 supplied, for example, by Morgan Matroc Trans-